Geostationary Operational Environmental Satellite (GOES) – R Series

ABI L2+ Cloud Top Parameters (Height, Temperature, and Pressure) Beta, Provisional and Full Validation Readiness, Implementation and Management Plan (RIMP)

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ABI L2+ Cloud Top Parameters (Height, Temperature, and Pressure)
Beta, Provisional and Full Validation
Readiness, Implementation and Management Plan (RIMP)

Submitted by:

Signatures can be viewed in the CMO file 09/26/2016

Matthew Seybold
GOES- R Product Readiness and Operations Manager

Concurred by:

Signatures can be viewed in the CMO file

10/20/2016
Jaime Daniels Date
GOES-R Algorithm Working Group Lead

Signatures can be viewed in the CMO file

11/02/2016
Edward Grigsby Date
GOES-R Program Systems Engineering Lead

Signatures can be viewed in the CMO file

11/15/2016
Raymond Pages Date
GOES-R Ground Chief Project Engineer

Approved by:

Signatures can be viewed in the CMO file

11/29/2016
James Valenti Date
GOES-R Ground Segment Project Manager

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Preface

The evolving calibration and validation (cal/val) maturity of Geostationary Operational Environmental Satellite R-Series (GOES-R) products throughout the beginning of the mission is described by three levels: Beta, Provisional, and Full validation. The Flight Project is responsible for producing the Level 1b (L1b) products according to the Level III requirement documents. Once Beta Maturity of the L1b products is achieved, the Level 2+ (L2+) will begin analysis towards Beta maturity. Further levels of maturity (Provisional and Full validation) require additional and often long-term activities. A detailed description of the three product maturity levels is given in Figure 1, but brief descriptions of the three maturity levels are:

Beta: the product is minimally validated and may still contain significant errors; based on product quick looks using the initial calibration parameters.
Provisional: product performance has been demonstrated through a large, but still (seasonally or otherwise) limited, number of independent measurements. The analysis is sufficient for limited qualitative determinations of product fitness-for-purpose, and the product is potentially ready for testing operational use.
Full: product performance has been demonstrated over a large and wide range of representative conditions, with comprehensive documentation of product performance, including known anomalies and their remediation strategies. Products are ready for operational use.

Assessment and declaration of maturity levels is performed during Peer Stakeholder–Product Validation Reviews (PS-PVRs). At each PS-PVR, the status of products will be presented by members of the cal/val science teams. For L2+ products, Beta maturity PS-PVRs are held in close proximity with and prior to Operations Handover. The review panel at the PS-PVRs will include the GOES-R Operational Readiness Working Group (GORWG), GOES-R Program System Engineering (PSE), NOAA Office of Satellite and Product Operations (OSPO), and GOES-R Product Readiness and Operations (PRO). The Readiness, Implementation, and Management Plans (RIMPs) have been created to document the analysis techniques, methodology, duration, tools, data, resources, staffing, and schedule of the Post-Launch Product Tests (PLPTs) to be used by the cal/val science teams to demonstrate the different levels of product maturity. The primary purpose of the RIMPs is to act as a planning resource for the cal/val teams as they prepare for Launch. Additionally, the RIMPs can be used by other members of the GOES-R Program to prepare for cal/val activities, to assess the suitability of the cal/val test plans, and to understand the data and resource requirements the science teams have. Cal/val testing is likely to reveal necessary algorithm changes to evolve the product quality through the maturity levels. The Algorithm Change Management Plan (ACMP) will be used to track and implement these algorithm changes.

The introspection necessary to create these RIMPs has led to extensive consultations between the cal/val teams and other groups within the GOES-R Program, including the Flight Project, the Ground Segment, and a team of experts from The Aerospace Corporation under contract from GOES-R PSE to help improve the cal/val mission. Figure 2 below describes the responsibilities and accountability of each of the main parties involved in the creation of the RIMPs. This delineation is required because GOES-R operations are to be handed over from the GOES-R Program to NOAA OSPO at the end of the PLT period, yet the process of validating product maturity will continue. This changing nature of accountability during the process must be acknowledged. Accountability of the RIMPs changes at Operations Handover from NASA to NOAA and is aligned with the level of each RIMPs' validation maturity objective. Accountability determines which organization owns documentation, process, and procedures. Responsibility determines which organization creates, executes, and maintains specific activities.

GOES-R Product (L1b and L2+) Maturity Levels

Beta Validation

Preparation Activities
- Initial calibration applied (L1b).
- Rapid changes in product input tables, and possibly product algorithms, can be expected.
- Product quick looks and initial comparisons with ground truth data (if any) are not adequate to determine product quality.
- Anomalies may be found in the product and the resolution strategy may not exist.

End state
- Products are made available to users to gain familiarity with data formats and parameters.
- Product has been minimally validated and may still contain significant errors.
- Product is not optimized for operational use.

Provisional Validation

Preparation Activities
- Validation and quality assurance (QA) activities are ongoing, and the general research community is now encouraged to participate.
- Severe algorithm anomalies are identified and under analysis. Solutions to anomalies are in development and testing.
- Incremental product improvements may still be occurring.
- Users are engaged in the Customer Forums (L2+ products only), and user feedback is assessed.

End state
- Product performance (L1b or L2+) has been demonstrated through analysis of a small number of independent measurements obtained from selected locations, periods, and associated ground-truth/field program efforts.
- Product analysis are sufficient to communicate product performance to users relative to expectations.
- Documentation of product performance exists that includes recommended remediation strategies for all anomalies and weaknesses. Any algorithm changes associated with severe anomalies have been documented, implemented, tested, and shared with the user community.
- Testing has been fully documented.
- Product ready for operational use and for use in comprehensive calibration/validation activities and product optimization.

Full Validation

Preparation Activities
- Validation, QA, and anomaly resolution activities are ongoing.
- Incremental product improvements may still be occurring.
- Users are engaged and user feedback is assessed.

End state
- Product performance for all products is defined and documented over a wide range of representative conditions via ongoing ground-truth and validation efforts.
- Products are operationally optimized, as necessary, considering mission parameters of cost, schedule, and technical competence as compared to user expectations.
- All known product anomalies are documented and shared with the user community.
- Product is operational.

Figure 1. GOES-R product maturity levels.

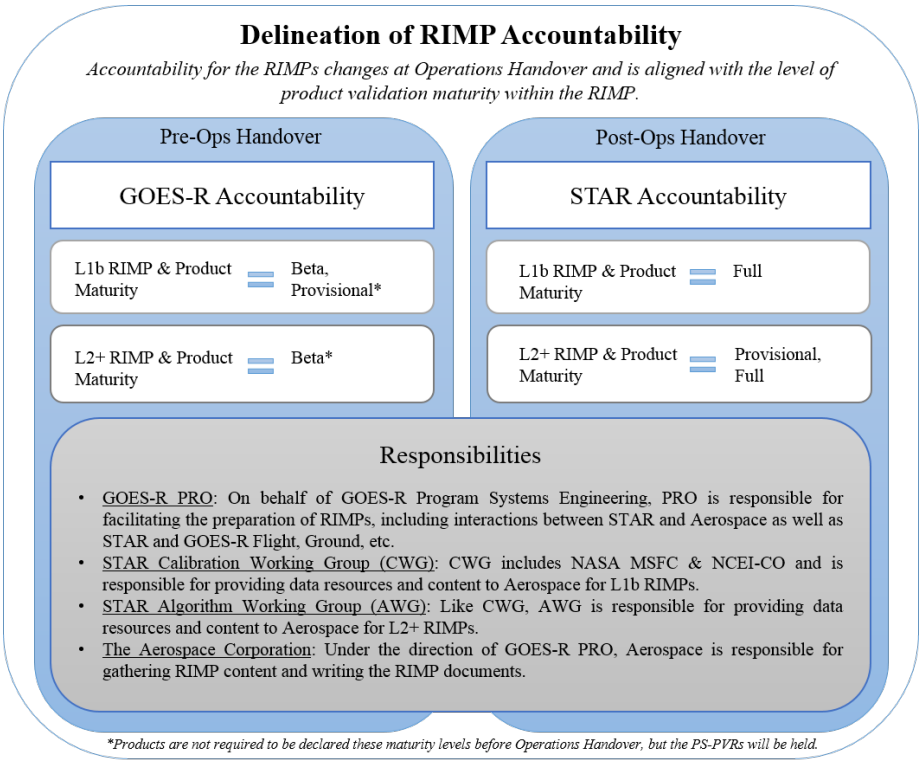

Figure 2. Delineation of accountability between GOES-R and STAR.

1. Cloud Top Parameters (CTP) Validation Overview

This Readiness, Implementation, and Management Plan (RIMP) covers all validation stages for the GOES-R Advanced Baseline Imager (ABI) Cloud Top Parameter (CTP) products. There are three stages in the validation process, Beta, Provisional, and Full Validation. Each stage is defined by Post-launch Product Tests (PLPT), which guide the overall validation process. The RIMP includes a summary of the methods and tools employed to prove the CTP set of products have met a given validation stage. Appendices are included that present more detail on each applicable PLPT and detail on the different data sets employed in the CTP validation process.

Because of the nature of the PLPT for the three cloud top parameters required by the GOES-R Program, these three products have been combined into one document. All three contain the same sequence of PLPTs, and in the majority of cases the only difference between them is the words height, temperature, and pressure. Furthermore the tools used to verify one of these is often used to verify the other two. Any exceptions are noted. No specific type of mesoscale scene is necessary for any of these three products, other than some should have clouds (a reasonable expectation). The CTP validation effort does not require any field campaign data, though it will be used in the full validation phase if available. No North/South (N/S) scan data is needed or used for the validation of CTP. National Weather Service (NWS) feedback will be via the Peer Stakeholder-Product Validation Review (PS-PVR) process, with additional insight from the National Center for Environmental Prediction (NCEP) and the Earth System Research Laboratory (ESRL).

To retain clarity in this document, all of the cloud top parameters will be referred to as CTP, while the specific parameter Cloud Top Pressure will use a small "p", i.e., CTp. The actual requirements have all CTP products produced on a "Hemisphere" instead of a Full Disk (FD), since only a FD scene can cover a hemisphere, it is assumed they are similar. The PLPT spreadsheet refers to a FD output, not hemisphere. For this document, the requirements are assumed to be verified by products derived from the FD, and the PLPT spreadsheet terminology will be used. Besides CTp, the other CTP products are Cloud Top Height (CTH) and Cloud Top Temperature (CTT).[1,3]

Eight PLPT events in the PLPT list have been defined to attain Beta maturity for the CTP set of products. Three of these state the CTPs are created at ABI Mode 3 for FD, CONUS, and mesoscale scenes and they are generated at the frequencies required. Two additional ones apply to FD and CONUS in ABI Mode 4. These five are all verified in the first week of PLPT, and are verified by OSPO. The remaining three require CTPs to be quantitatively analyzed (range, accuracy, and precision) with shortfalls documented, but only over a limited time frame. The range, accuracy, and precision related Beta PLPT events last approximately 10 weeks, occur in parallel, and also commence at the end of PLT.[1,2] PLPT events that support Beta maturity are listed below; details are in Appendix A:[1]

- **ABI-FD_CTH/CTT/CTp01:** verify the FD product generated every 15 minutes in ABI Mode 3.
- **ABI-CONUS_CTH/CTp01:** verify the CONUS product generated every 5 minutes in ABI Mode 3.
- **ABI-MESO_CTH/CTT01:** verify the mesoscale product generated every 5 min in ABI Mode 3.
- **ABI-FD_CTH/CTT/CTp02:** verify the FD product generated every 5 minutes in ABI Mode 4.
- **ABI-CONUS_CTH/CTT02:** verify the CONUS product generated every 5 minutes in ABI Mode 4.

- **ABI-FD_CTH/CTT/CTp03:** determine the extent to which the CTP FD products meet the Mission Requirements Document (MRD) product specification over a very limited number of independent measurements.
- **ABI-CONUS_CTH/CTT/CTp03:** determine the extent to which the CTP CONUS products meet the MRD product specification over a very limited number of independent measurements.
- **ABI-MESO_CTH/CTT02:** determine the extent to which the CTP mesoscale products meet the MRD product specification over a very limited number of independent measurements.

The following Table identifies the frequency of each scan type for Modes 3 and 4. It includes the required cadence of the CTP products as defined by both the GOES-R Functional and Performance Specification (F&PS) and the Product User's Guide (PUG). The bottom three lines reflect, for each appropriate scan type, the frequency of that product used for verification purposes. Any validation that occurs will use the frequency of the operational output, as indicated in the Table. Note the F&PS and the PUG do not agree, as the PUG is a forward looking document that reflects the frequency at which the ground system will actually produce the product. That is the product frequency to be used for validation. Note there is no CTT product for CONUS in Mode 3, no CTp product for mesoscale in Mode 3, and no CTp product for CONUS in Mode 4, according to both documents.

** There is no CONUS scan type for Mode 4, but there are required products over the CONUS that are derived from the FD output*

Mode	Mode 3			Mode 4		
Scan Type	FD	CONUS	Mesoscale	FD	CONUS*	Mesoscale
Scan Freq	15 min	5 min	30 sec	5 min	5 min	N/A
CTH – F&PS	60 min	60 min	5 min	60 min	60 min	N/A
CTH - PUG	15 min	5 min	5 min	5 min	5 min	N/A
CTp – F&PS	60 min	60 min	N/A	60 min	60 min	N/A
CTp – PUG	15 min	5 min	N/A	5 min	5 min	N/A
CTT – F&PS	15 min	N/A	5 min	15 min	N/A	N/A
CTT – PUG	15 min	N/A	5 min	5 min	N/A	N/A
CTH – Ver Freq	15 min	5 min	5 min	5 min	5 min	N/A
CTp -Ver Freq	15 min	5 min	N/A	5 min	N/A	N/A
CTT – Ver Freq	15 min	N/A	5 min	5 min	5 min	N/A

Table 1. CTP documented product cadence and verification approach

Three events in the PLPT list have been defined to attain Provisional maturity. The Provisional stage brings in user community feedback while increasing the amount of statistical verification indicative of the true performance of the CTP products. In a broad sense, to declare Provisional maturity, these events must validate that the quality of the CTP has been assessed sufficiently to characterize the CTP products to the user community. The Provisional events last 24 weeks, occur in parallel, and commence immediately after Beta has been attained.[1,2] PLPT events that support Provisional maturity are listed below; details are in Appendix A: [1]

- **ABI-FD_CTH/CTT/CTp04:** assess the accuracy and precision of the CTP FD products over a large and wide range of representative conditions.
- **ABI-CONUS_CTH/CTp04:** assess the accuracy and precision of the CTP CONUS products over a large and wide range of representative conditions.
- **ABI-MESO_CTH/CTT03:** assess the accuracy and precision of the CTP mesoscale products over a large and wide range of representative conditions.

The criteria by which the GOES-R CTP products will be evaluated to determine if Provisional status has been met are:

- Assess the accuracy and precision of all cloud top parameters over a large and wide range of representative conditions.
- Document impacts from challenges with upstream dependencies.
- The following requirements must be met at Provisional for all ABI modes and all cloud top products; horizontal resolution, mapping accuracy, and measurement range (for the CONUS cloud top height measurement range, the values for the hemispheric mode will be used, since the documented CONUS cloud top height measurement range is in the wrong units).
- Accuracy and precision do not have to be met to attain Provisional status, however, if they do not do so, the reasons behind not meeting these requirements must be documented, to include reporting of incidents/issues as an Algorithm Discrepancy Report (ADR) for discussion at the Algorithm Action Review Team (AART).
- Have remediation strategies in place for known issues.
- Product is ready for potential operational use (user recommendation) and for use in scientific publications.

Moving to the final stage of validation, simply referred to as Full, the CTP products must now show they have at least met all of the documented requirements, most importantly those of measurement accuracy and precision. They must also be of operational quality. This does depend upon an accurate Clear-Sky Mask (CSM), and hence the schedule of validation activities must account for the time it takes the CSM to attain Full Validation. For the CTP products, it will take 6 months beyond the CSM attaining Full Validation for the CTP products to reach Full Validation themselves. Note the work to prove Full Validation has been met may start before the CSM itself has reached the Full Validation stage.

Requirements for the various CTP products are consistent across the different scene types (FD, CONUS, and mesoscale), simplifying the approach to validate the PLPT events below. Note there is no requirement for a mesoscale CTp product, however, not only is a mesoscale CTp product produced, but there are requirements for mesoscale Cloud Top Height and Temperature. Therefore the mesoscale CTp will be validated assuming CONUS CTp requirements, except for mapping accuracy and refresh rate, which will be treated similarly to the other mesoscale CTP products. The accuracy and precision requirements for CTP products only apply to daytime conditions where the solar zenith angle is within 62 degrees (65 for CTH), though all CTP products are produced independent of day or night conditions. The methods and tools necessary to prove the Full Validation stage are the same as those for proving Provisional. Events that support Full Validation maturity are listed below; details are in Appendix A: [1]

- **ABI-FD_CTH/CTT/CTp05:** assess the accuracy and precision of the CTP FD products over a large and wide range of representative conditions sufficient to prove all CTP product requirements have been met.
- **ABI-CONUS_CTH/CTp05:** assess the accuracy and precision of the CTP CONUS products over a large and wide range of representative conditions sufficient to prove all CTP product requirements have been met.
- **ABI-MESO_CTH/CTT04:** assess the accuracy and precision of the CTP mesoscale products over a large and wide range of representative conditions sufficient to prove all CTP product requirements have been met.

Besides the criteria necessary to meet Provisional, all of which apply to Full Validation, the following must also be met to achieve the Full Validation stage:

- A measurement accuracy of 500 m and precision of 1500 m, for all clouds with an emissivity greater than 0.8, must be met for each CTH product (FD, CONUS, and mesoscale).
- A measurement accuracy of 50 mb and precision of 150 mb, for all clouds with an emissivity greater than 0.8, must be met for each CTp product (FD, CONUS, and mesoscale).
- A measurement accuracy of 3 Kelvin and precision of 5 Kelvin, for all clouds with an emissivity greater than 0.8, must be met for each CTT product (FD, CONUS, and mesoscale).
- If the accuracy and precision requirements are not met due to errors with upstream data sources, to include the CSM, these must be documented appropriately.

The CTP products at handover are to be, at a minimum, at the Beta stage of verification. For the CTP products, Beta is defined as the CTP products being quantitatively analyzed over a limited data set with any anomalies and shortfalls properly documented.[1,2,15]

The validation processes and procedures, monitoring and analysis methods, tools, and expected output artifacts are described in the following sections. The details of each PLPT are contained in Appendix A and of each reference data set are in Appendix B.

2. Schedule of Events

Figure 3 shows the GOES-R validation schedule. System Performance Operation Test (SPOT) begins 44 days after launch when ABI L1b and the L2 Cloud and Moisture Imagery (CMI) Key Performance Beta evaluation begins and should be declared Beta maturity by L+87 days. One day later, the GOES Rebroadcast (GRB) will be populated with that data. The L2 products must reach Beta maturity by handover at L+197 days, the same time that ABI L1b and CMI must reach Provisional. Given that L2 Beta tests require at least 6 weeks, L2 Beta testing must get underway by L+155 days, but can begin as soon as the ABI L1b and CMI reach Beta (L+87 days).

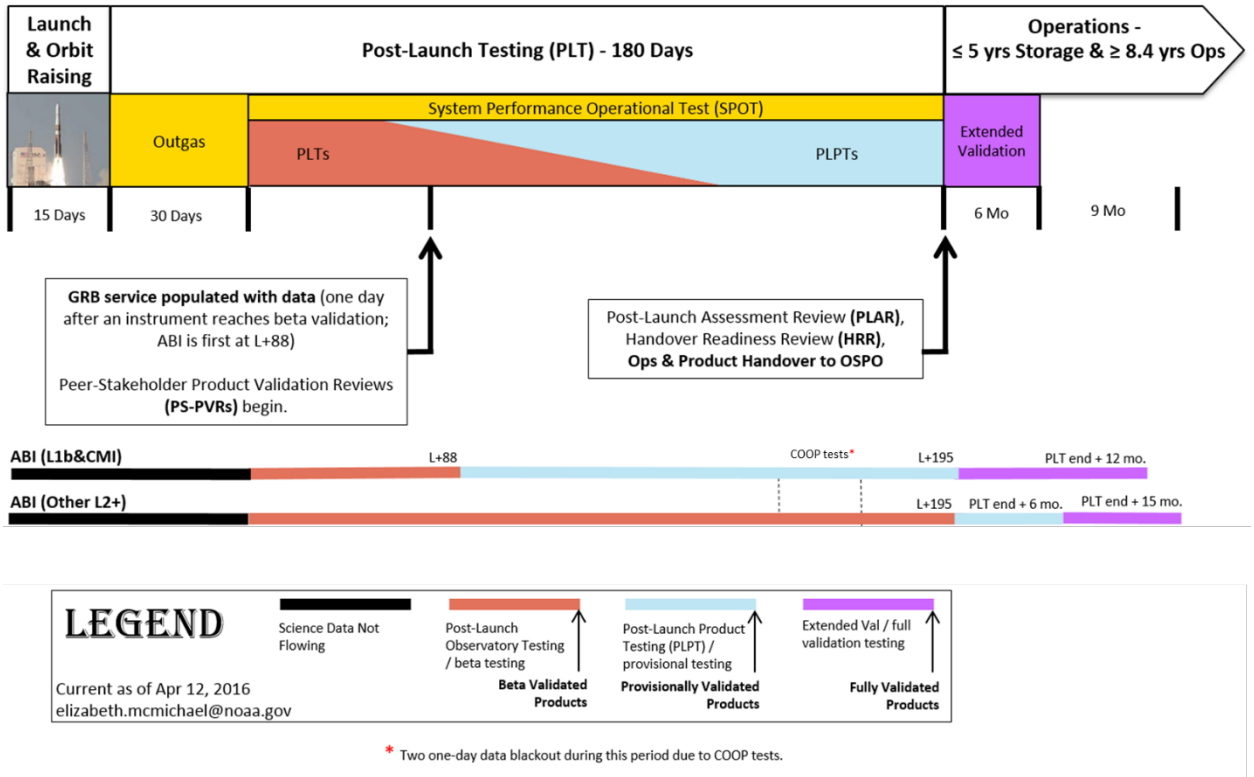

Figure 3. Schedule of events.

The GOES-R Operations phase begins after handover marking the start of a 12 month Extended Validation period for ABI L1b and CMI, which is coincident with the start of the 6 month L2 Provisional evaluation, followed by another nine months period for L2 products to reach Full maturity, 15 months after handover. The CTP schedule contains some margin against the no later than dates.

A schedule of specific CTP activities includes:

- Current – December 2015: finish testing all CTP validation tools.
- Current – September 2016: evaluate results using data from DOE-3 and -4.
- Current – October 2016: test and evaluate algorithm with Himawari 8 data.
- July 2016 complete final version of all CTP validation tools.
- L+70 days: begin CTP Beta cal/val activities.
- L+77 days: complete verification of cadence requirements (OSPO).
- L+140 days: complete Beta Validation activities (no later than date L+197 days).

- L+300 days: complete Provisional phase of validation (no later than date L+337 days).
- L+620 days: complete all phases of validation (no later than date L+647 days).

Other aspects related to schedule include:

- The initial Beta testing will focus on the CTP being produced at the proper cadence for each of FD, CONUS, and mesoscale for both ABI Modes 3 and 4[1].
- This initial testing will take one week[1].
- Simultaneously, but to continue through the entire Beta period, the CTP products will be quantitatively compared to data sets as described in section 4[1,2,6,7].
- Additional cloud top parameter output will be brought in and/or produced at CIMSS to compare with the GOES-R CTP products starting with the Provisional phase[1,6,7].
- Any issues with data access to any CTP product will directly impact the schedule of CTP validation activities.
- The time frame for Provisional assumes the CSM attains its Provisional schedule, if not the impact is linear with the delays in the CSM Provisional work.
- The CTP products takes precedence over cloud optical products since they precede the computation of these products in the cloud chain, but they are secondary to the CSM and Cloud Phase[10,15].

3. Roles and Responsibilities

3.1 Primary Point of Contact

The primary point of contact (POC) for leading the CTP validation effort and algorithm updates is Dr. Andy Heidinger[1,6,7].

3.2 GOES-R Point of Contact

The primary POC at GOES-R for the CTP validation effort is Wayne MacKenzie.

3.3 Test Analyst/Engineer

Steve Wanzong will lead the analysis of the PLPTs under Chris Velden's direction.

3.4 GOES-R Feedback

Formal feedback to the GOES-R program regarding CTP products will be provided by the cloud product lead, Dr. Andy Heidinger[15].

3.5 Level of Effort

Dr. Andy Heidinger and Steve Wanzong will each be at 0.5 FTE.

4. Tools

The CTP validation methodology includes a set of seven tools; for details refer to Appendix C. Colocation tools operate to collocate clouds identified by independent platforms, such as CALIPSO, with GOES-R pixels and the associated CTP output. The analysis tools either enable visualization of the results and/or provide for the necessary statistical comparisons that indicate if CTP has achieved a given validation stage. These tools also tie the CTP validation to that of the Clear Sky Mask (CSM), so false clouds may be removed from the analysis. The same tools are used throughout the CTP validation process.

5. Analysis Methods

5.1 Method 1: Quantitative comparisons with "truth" data[1,6,7]

- CTP results will be compared to CALIPSO and ARM results[1,6,7].
- This heritage method has been used with prior sensors such as VIIRS[2,7].
- Tools which collocate CALIPSO and ARM CTP measurements with the output from GOES-R, especially patmosx_colocate_1km.pro and plot_acha_val.pro, will provide the primary statistical basis to prove Beta and Provisional [6,7].
- The CTP products, for all scene types, will be evaluated for range, accuracy, and precision, though of these three only range requirements must be met for Provisional[1,3].
- Due to inconsistencies and errors in the GOES-R CTP requirement values, accuracies, precisions, and ranges will be evaluated according to the most restrictive of the three categories (FD, CONUS, and mesoscale) regardless of the wording in the F&PS; this does not apply to resolution, mapping accuracy, or latency requirements[3,15].

5.2 Method 2: Qualitative comparisons with CTP products derived from other sensors[1,6,7]

- CTPs derived from MODIS and VIIRS will be used to compare to the GOES-R CTP products[1,6,7].
- This heritage method has been used with prior sensors as a way to check consistency among the different results[6,7].
- Significant differences indicate issues on a larger scale not possible with available truth data noted above[6,7,11].
- Any anomalies identified through this method will be properly documented as part of fulfilling the criteria for all three phases of validation[15].
- Displays of the CTP results derived from other sensors will be placed side-by-side, primarily using GLANCE, with the matching GOES-R locations to note if any large disparities are observed in the GOES-R CTP products[7].

The primary method to evaluate CTP is match-up data with sensors of sufficient quality to be considered "truth", via Method 1. Statistics will be derived which compare the results of the GOES-R CTPs with those derived from other satellites via Method 2. Displays of the GOES-R CTP will be displayed over a range of conditions to verify the products produce reasonable results for a variety of cloud types[1,3]. Side-by-side examples will also be included to reveal the consistency of GOES-CTP output with that derived from other sensors, primarily using GLANCE[1,6,7,12]. The time allocated to proving the beta phase is sufficient to verify the different types of clouds the CTP algorithm must operate on (e.g. fog/stratus, cirrus, etc.), though seasonal events may be missed during PLPT depending on the exact 30 day period (will it be spring/fall or summer/winter)[15].

6. Output Artifacts

6.1 Beta Maturity Artifacts

The two criteria for declaring Beta maturity as indicated in section 1.0 are: (1) quantitatively assess the performance of the CTP products with a limited set of data; and (2) identify any issues with the CTP products. Range, accuracy, and precision performance and product issues will be documented in a Beta test report.

6.1.1 These tests of priority 1 all must pass in order to achieve Beta maturity:

- ABI-FD_CTH/CTT/CTp01
- ABI-CONUS_CTH/CTp01
- ABI-MESO_CTH/CTT01
- ABI-FD_CTH/CTT/CTp02
- ABI-CONUS_CTH/CTp02
- ABI-FD_CTH/CTT/CTp03
- ABI-CONUS_CTH/CTp03
- ABI-MESO_CTH/CTT02

6.1.2 The CTP Beta maturity validation effort does not include any tests of priority 2.

6.2 Provisional Maturity Artifacts

The criteria for declaring Provisional maturity are described in section 1.0. Range, accuracy, and precision performance and product issues will be documented through the PS-PVR process via a power point presentation.

6.2.1 The following tests of priority 1 must pass in order to achieve Provisional maturity:

- ABI-FD_CTH/CTT/CTp04
- ABI-CONUS_CTH/CTp04
- ABI-MESO_CTH/CTT03

6.2.2 The CTP Provisional maturity validation effort does not include any tests of priority 2.

6.3 Full Validation Maturity Artifacts

The criteria for declaring Full maturity are described in section 1.0. Range, accuracy, and precision performance and product issues will be documented through the PS-PVR process via a power point presentation.

6.3.1 The following test of priority must pass in order to achieve Full validation maturity:

- ABI-FD_CTH/CTT/CTp05
- ABI-CONUS_CTH/CTp05
- ABI-MESO_CTH/CTT04.

6.3.2 The CTP Full validation maturity validation effort does not include any tests of priority 2.

6.4 Key Artifacts

Key artifacts for the CTP validation effort are the presentation of the statistical accuracy of the CTPs as derived from comparisons to CALIPSO and ARM sites through the reports and presentations noted in sections 6.1 through 6.3. [2,7].

6.5 More Output Artifacts

There are no additional artifacts for CTP.

6.6 Delivery Schedule

The delivery schedule of artifacts for the CTP validation effort is tied to the schedule for completing beta, provisional, and full validation as given in section 2. All statistical analysis necessary to prove a given validation stage will be included in a power point presentation in time for the appropriate PS-PVR.

7. Pre-launch

The following activities have been completed during pre-launch.

- The only pre-launch verification of the CTP is to insure the format and data content are correct[2,4,15].
- Pre-launch work has exercised the ability to produce simulated CTP output from NWP[7].
- Examples based on proxy SEVIRI data also give confidence to the tools intended for GOES-R CTP analysis[6,7].
- Output from the DOEs were used to verify that the tools can properly read and use applicable diagnostics; this was the only remaining pre-launch activity for the CTP[15].
- The Cloud cal/val team will used output from DOE-3 and will use DOE-4 to verify use of their tools with the proper diagnostics[15].
- Data flow for DOE output is through STAR[15].

8. References

[1] Verification Event (VE) spreadsheet (PLPT_Validation_Event_List_L2_v0_1_20140903_with_Post-PLT_Entries).
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[15] Interview with the Cloud Product Team, June 2, 2015.
[16] http://www.arm.gov/about (ARM descriptions and data source).
[17] GOES-R Field Campaign Preparation, October 26, 2015.

A. Appendix A: Validation Events

A.1 PLPT Events that Support Beta Maturity

A.1.1 Event Name: ABI-FD_CTH/CTT/CTp01[1]

Objective: Verify that product is generated every 15 minutes for FD output[3].
Start Time: Start of PLPT[1].
Duration: 1 week[1].
ABI Mode: Mode 3[1].
GOES-R Data Type(s): 15 minute FD/Hemisphere[1,3].
Beta Success Criteria: Product generated and falls within expected measurement range; all that is required for this PLPT is that the product is created and received at the validation site with a 1 hour cadence[1,3].
Dependencies: That the CTP products are created by the ground system and delivery of such product to the cal/val team is sufficient to keep up with the cadence of the FD[1,4].
PLPT Lead: Chris Velden[15].
PLPT Analyst: Steve Wanzong[15].
Validation Data: None (quality assessed in a different PLPT)[1].
Procedural References: None (quality assessed in a different PLPT)[1].
Comparison/Reference Data: B.1, B.2, and B.3.
Monitoring and Analysis Method: Product inspection, either the CTPs are produced at the correct cadence or it is not.[1,3].

A.1.2 Event Name: ABI-CONUS_CTH/CTp01

Same as for ABI-FD_CTH/CTT/CTp01 except for:
GOES-R Data Type(s): 5 minute CONUS[1,3].

A.1.3 Event Name: ABI-MESO_CTH/CTT01

Same as for ABI-FD_CTH/CTT/CTp01 except for:
GOES-R Data Type(s): 5 min mesoscale [1,3].

A.1.4 Event Name: ABI-FD_CTH/CPP/CTp02

Same as for ABI-FD_CTH/CTT/CTp01 except for:
ABI Mode: Mode 4[1].
GOES-R Data Type(s): 5 minute FD/Hemisphere

A.1.5 Event Name: ABI-CONUS_CTH/CTT02

Same as for ABI-FD_CTH/CTT/CTp01 except for:
ABI Mode: Mode 4[1].

A.1.6 Event Name: ABI-FD_CTH/CTT/CTp03

Objective: Determine the extent to which the CTP products meet the relevant MRD product specifications over a very limited number of independent measurements.[1]
Start Time: Start of PLPT[1].
Duration: 30 days[1].
ABI Mode: Mode 3[1].
GOES-R Data Type(s): 15 minute FD/Hemispheric CTPs[1].
Beta Success Criteria: The FD CTPs are quantitatively assessed for a limited set of independent measurements, and any issues are properly identified. No quantitative requirements for accuracy, range, or precision is needed to be met for Beta, but any shortfalls must be adequately documented.

This must occur with a product horizontal resolution of 10 km and a mapping accuracy of 5 km for CTH and CTp, a horizontal resolution of 2 km with a mapping accuracy of 1 km (IR pixel resolution) for CTT, and with a cadence of 15 minute products. [1,2,6,7]
Dependencies: That the CTP products are created by the ground system and delivery of such products to the cal/val team is sufficient to keep up with the cadence of FD/Hemispheric CTP output[1,3].
PLPT Lead: Andy Heidinger[6,7].
PLPT Analyst: Steve Wanzong[9].
Validation Data: Overlapping data from CALIPSO and ARM[1,6].
Procedural References: Section 5, methods #1 and 2.
Comparison/Reference Data: All available sets in Appendix B.
Monitoring and Analysis Method: Derive statistics using the match-up data as truth, and produce comparative statistics with CTPs generated over the same area as GOES-R but derived from MODIS and VIIRS.[1,6,7]

A.1.7 Event Name: ABI-CONUS_CTH/CTp03

Same as for ABI-FD_CTH/CTT/CTp04 except for:
GOES-R Data Type(s): 5 minute CONUS CTPs[1,3].
Beta Success Criteria: The CONUS CTPs are quantitatively assessed for a limited set of independent measurements, and any issues are properly identified. No quantitative requirements for accuracy, range, or precision is needed to be met for beta, but any shortfalls must be adequately documented. This must occur with a horizontal resolution of 10 km and a mapping accuracy of 5 km, at a 5 minute cadence (there are no requirements for CTT for CONUS).[1,2,6,7]

A.1.8 Event Name: ABI-MESO_CTH/CTT02

Same as for ABI-FD_CTH/CTT/Ctp04 except for:
GOES-R Data Type(s): 5 min mesoscale CTP[1,3].
Beta Success Criteria: The mesoscale CTPs are quantitatively assessed for a limited set of independent measurements, and any issues are properly identified. No quantitative requirements for accuracy, range, or precision is needed to be met for Beta. This must occur with a product horizontal resolution of 2 km and a mapping accuracy of 1 km for CTT, a horizontal resolution of 4 km and a mapping accuracy of 2 km for CTH, and at a 5 min cadence (there are no requirements for CTp for mesoscale).[1,2,6,7]

A.2 PLPT Events that Support Provisional Maturity

A.2.1 Event Name: ABI-FD_CTH/CTT/CTp04[1]

Objective: Assess the accuracy and precision of the CTP products over a large and wide range of representative conditions[1].
Start Time: Immediately following Beta[1].
Duration: 4 months[1].
ABI Mode: Mode 3[1].
GOES-R Data Type(s): 5 minute FD/Hemispheric CTPs[1].
Provisional Success Criteria: The FD CTPs meet their quantitative requirements for a limited/seasonal set of independent measurements. The results must be sufficient to inform users of the status and capabilities of the CTP products.[1,2,6,7]
Dependencies: The CTPs has reached the Beta level of maturity[1,2,4].
PLPT Lead: Andy Heidinger[1,6,7].
PLPT Analyst: Steve Wanzong[9].
Validation Data: Overlapping data from CALIPSO and ARM[6,7].
Procedural References: Section 5, methods #1 and 2.

Comparison/Reference Data: All available sets in Appendix B.
Monitoring and Analysis Method: Derive statistics using the match-up data as truth, and produce comparative statistics with CTPs generated over the same area as GOES-R but derived from MODIS and VIIRS.[1,6,7]

A.2.2 Event Name: ABI-CONUS_CTH/CTp04

Same as for ABI-FD_CTH/CTT/CTp04 except for:
GOES-R Data Type(s): 5 minute CONUS CTPs[1].

A.2.3 Event Name: ABI-MESO_CTH/CTT03

Same as for ABI-FD_CTH/CTT/CTp04 except for:
GOES-R Data Type(s): 5 min mesoscale CTP[1].

A.3 PLPT Events that Support Full Validation Maturity

A.3.1 Event Name: ABI-FD _CTH/CTT/CTp05[1]

Objective: Assess the accuracy and precision of the CTP products over a large and wide range of representative conditions sufficient to prove all CTP product requirements have been met[1].
Start Time: Immediately following Provisional[1].
Duration: 1 year[1].
ABI Mode: Mode 3[1].
GOES-R Data Type(s): 15 minute FD/Hemispheric CTPs[1].
Validated Success Criteria: The FD CTPs meet their quantitative requirements as shown by, at a minimum, an annual set of independent measurements. The results must be sufficient to verify all requirements and to inform users of the status and capabilities of the CTP products.[1,2,6,7]
Dependencies: The CTPs has reached the Provisional level of maturity[1,2,4].
PLPT Lead: Andy Heidinger[1,6,7].
PLPT Analyst: Steve Wanzong[9].
Validation Data: Overlapping data from CALIPSO and ARM[6,7].
Procedural References: Section 5, methods #1 and 2.
Comparison/Reference Data: All available sets in Appendix B.
Monitoring and Analysis Method: Derive statistics using the match-up data as truth, and produce comparative statistics with CTPs generated over the same area as GOES-R but derived from MODIS and VIIRS.[1,6,7]

A.3.2 Event Name: ABI-CONUS_CTH/CTp05

Same as for ABI-FD_CTH/CTT/CTp04 except for:
GOES-R Data Type(s): 5 minute CONUS CTPs[1].

A.3.3 Event Name: ABI-MESO_CTH/CTT04

Same as for ABI-FD_CTH/CTT/CTp04 except for:
GOES-R Data Type(s): 5 min mesoscale CTP[1].

B. Appendix B: GOES-R and Validation Reference Data

B.1 Data Set #1: ABI-L2-ACHA[3]

Storage Location: CIMSS Data Center[15].
Access Process: Product Distribution and Access (PDA) or STAR[4,15].
POC: Jerald Robaidek[15].
Spatial Coverage: All ABI modes, FD, CONUS, and mesoscale [1,3].
Temporal Coverage: All ABI modes, 15 minutes for FD, 5 mins for CONUS and mesoscale [1,3].
Contingency: None, this the GOES-R cloud top height product the team must validate, there is no validation without the core product.
Special Considerations: The cloud product team expects to obtain this data through PDA, but the status of that is unclear. The data may also be obtained through STAR, though with a delay of unknown extent.

B.2 Data Set #2: ABI-L2-CTP[3]

Storage Location: CIMSS Data Center[16].
Access Process: PDA or STAR[4,15].
POC: Jerald Robaidek[15].
Spatial Coverage: All ABI modes, FD, CONUS, and mesoscale [1,3].
Temporal Coverage: Ala ABI modes, 15 minutes for FD, 5 mins for CONUS and mesoscale [1,3]
Contingency: None, this is the cloud top pressure product the team must validate, there is no validation without the core product.
Special Considerations: The cloud product team expects to obtain this data through PDA, but the status of that is unclear. The data may also be obtained through STAR, though with a delay of unknown extent.

B.3 Data Set #3: ABI-L2-ACHT[3]

Storage Location: CIMSS Data Center[15].
Access Process: PDA or STAR[4,15].
POC: Jerald Robaidek[15].
Spatial Coverage: All ABI modes, FD, CONUS, and mesoscale [1,3].
Temporal Coverage: All ABI modes, 15 minutes for FD, 5 mins for CONUS and mesoscale [1,3].
Contingency: None, this is the cloud top temperature product the team must validate, there is no validation without the core product.
Special Considerations: The cloud product team expects to obtain this data through PDA, but the status of that is unclear. The data may also be obtained through STAR, though with a delay of unknown extent.

B.4 Data Set #4: CALIPSO[1,6,7]

Storage Location: Science Investigator-led Processing System (SIPS)[15].
Access Process: Public internet[8,15].
POC: Liam Gumley[8,15].
Spatial Coverage: 333 m across track, 1-5 m along track[8].
Temporal Coverage: Not applicable.
Contingency: If Cloud Aerosol Transport System (CATS) data is available it is capable of replacing CALIPSO, should the CALIPSO become unavailable after the launch of GOES-R, then CATS data will be used instead [15].
Special Considerations: The CALIOP sensor on CALIPSO measures clouds and aerosols via lidar, and is often used to verify many aspects of clouds, including cloud top characteristics[8].

B.5 Data Set #5: Atmospheric Radiance Measurement (ARM) sites[1,6,7]
Storage Location: Science Investigator-led Processing System (SIPS)[15].
Access Process: NOAA Public internet (http://www.arm.gov/)[15].
POC: N/A[15].
Spatial Coverage: Gingle point locations[9].
Temporal Coverage: Hourly[9].
Contingency: Use CALIPSO as truth data.
Special Considerations: ARM locations include hourly measurements of cloud characteristics, which may be used as single point sources of truth for CTP verifications.[15]

B.6 Data Set #6: MODIS derived CTPs derived from MODIS L1b data[1]
Storage Location: SIPS[15].
Access Process: CLAVR-X[15].
POC: Liam Gumley[15].
Spatial Coverage: GOES coverage area[1,2].
Temporal Coverage: Not applicable.
Contingency: Use other available CTP products[1,7].
Special Considerations: The MODIS CTPs use an algorithm designed and led by CIMSS. It may be executed on site at SSEC.[12,15]

B.7 Data Set #7: VIIRS derived CTPs derived from VIIRS SDRs[1].
Storage Location: CLASS and SIPS[15].
Access Process: Either computed on CLAVR-X or public internet access to CLASS[12,15].
POC: Liam Gumley, Cloud Product Team[15].
Spatial Coverage: GOES coverage area[1,2].
Temporal Coverage: Not applicable.
Contingency: Use other available CTP products[1,7].
Special Considerations: The VIIRS CTP products are run operationally on the IDPS owned by the JPSS program and stored for archive in CLASS, but it may also be recreated locally at CIMSS through the CLAVR-X architecture.[13,15]

B.8 Data Set #8: GOES L1b[1]
Storage Location: CIMSS Data Center[15].
Access Process: PDA or STAR[15].
POC: Jerald Robaidek[15].
Spatial Coverage: GOES coverage area that is collocated with the VIIRS sensor[5,7].
Temporal Coverage: All imagery under ABI Mode 3 or 4[1,3].
Contingency: The GOES CTPs use an algorithm designFed and led by CIMSS. It may be executed on site at SSEC.[15]
Special Considerations: CLAVR-X has the ability to generate CTPs from GOES radiances, the actual comparisons are through the GLANCE tool noted in section 4.0 (Tool #7).

B.9 Data Set #9: Field Campaign Data
Source: If available, cloud physics lidar (CPL) and the cloud radar system (CRS) placed on the ER-2 aircraft[11].
Access Process: TBD.
POC: Francis Padula
Frequency of transmission: Not applicable, any field campaign is a finite event[11].
Contingency if not available: Validation of the CTPs can be significantly benefited by field campaign data, but at this time it is not expected to be available before Beta or Provisional is completed. If any field campaign data is available during the final (Full Validation) stage, it will

be used as part of the quantitative verification process. Note however that validation will proceed independent of the availability of field campaign data.[1,6,7,17]

C. Appendix C: Tools

C.1 Tool #1: Man-computer Interactive Data Access System (McIDAS)[1,6,7].

Location: Cooperative Institute for Meteorological Satellite Studies (CIMSS)[6,7].
Description: In house, though tool itself is employed by many outside of CIMSS, McIDAS has the capability to display CTP output from numerous sensors over the original imagery, to include those produced from data sets B.1, B.6, B.7, and B.8[6,7].
Developer: Space Science Environmental Center (SSEC) McIDAS Programmers [15].
Development Schedule: Tool is ready for cal/val use with GOES-R, though certain diagnostic data has yet to be tested[15].
Data Dependencies: GOES-R, MODIS, and VIIRS CTP output[6,7].
Testing Accomplished or Planned: Testing has been accomplished with both surrogate and simulated GOES-R CTP output, the only remaining testing is with diagnostics that are expected with upcoming DOE testing[15].
POC: McIDAS Users Group (MUG)[15].

C.2 Tool #2: patmosx_colocate_1km.pro[15]

Location: CIMSS[15].
Description: In house tool that collocates cloud product files, either the GOES-R CTP products or those derived from data sets B.6, B.7, or B.8 in Appendix B, with CALIOP L2 1 km cloud layer data files[15].
Developer: CIMSS[15].
Development Schedule: Development for this tool has been completed[15].
Data Dependencies: GOES-R, MODIS, and VIIRS CTP output and CALIOP data[6,7,15].
Testing Accomplished or Planned: Testing has been all but completed, a minor amount of testing remains with output that includes diagnostics, as planned in upcoming DOEs[15].
POC: Cloud Product Team[15].

C.3 Tool #3: plot_calipso_matchup.pro[15]

Location: CIMSS[15].
Description: In house tool that plots cloud output, including CTP output, with CALIOP 1 km cloud layer data files[15].
Developer: CIMSS[15] .
Development Schedule: Development for this tool has been completed[15].
Data Dependencies: GOES-R, MODIS, and VIIRS CTP output and CALIOP data[6,7,15].
Testing Accomplished or Planned: Testing has been all but completed, a minor amount of testing remains with output that includes diagnostics, as planned in upcoming DOEs[15].
POC: Cloud Product Team[15].

C.4 Tool #4: make_training_data.pro[15]

Location: CIMSS[15].
Description: In house tool which creates a save file from the data and results created by other tools employed in the CTP cal/val process[15].
Developer: CIMSS[15].
Development Schedule: Development for this tool has been completed[15].
Data Dependencies: CLAVR-X and CALIOP 1 km cloud layer data, see tool #7[15].
Testing Accomplished or Planned: Testing has been all but completed, a minor amount of testing remains with output that includes diagnostics, as planned in upcoming DOEs[15].
POC: Cloud Product Team[15]

C.5 Tool #5: plot_acha_val.pro[15]

Location: CIMSS[15].
Description: In house tool which computes statistics of CTP output determined through CLAVR-X (tool #7) and compares them to CALIOP 1 km cloud layer data, then create plots from those outputs[15].
Developer: CIMSS[15].
Development Schedule: Development for this tool has been completed[15]
Data Dependencies: CTP output derived from CLAVR-X along with CALIOP 1 km cloud layer data, see tool #7[15].
Testing Accomplished or Planned: Testing has been all but completed, a minor amount of testing remains with output that includes diagnostics, as planned in upcoming DOEs[15].
POC: Cloud Product Team[15].

C.6 Tool #6: GLANCE[1,6,7]

Location: CIMSS[6,7].
Description: GLANCE allows users to perform inter-comparisons, in this case among CTP products from different sources, or between CTP products created from the same source but through different methods or with different inputs, to include the L1b/SDR data sets noted in Appendix B [15].
Developer: CIMSS in collaboration with the Algorithm Integration Team (AIT)[15].
Development Schedule: AIT has completed development and it has been delivered to the Cloud Product Team[15].
Data Dependencies: GOES-R, GOES, VIIRS, MODIS, AVHRR CTP products or CTP output derived from their L1b/SDRs[15].
Testing Accomplished or Planned: AIT has completed its testing activities[15].
POC: AIT[15].

C.7 Tool #7: Clouds from AVHRR extended (CLAVR-x)[15].

Location: CIMSS[15].
Description: In the context of GOES-R cal/val, CLAVR-x is actually an architecture under which much of the validation for the CTPs will occur. The CLAVR-x architecture includes the capability of computing CTP output from a variety of sources, including GOES-R, GOES, MODIS, VIIRS, and AVHRR. The resulting CTP products are tied to the validation of the GOES-R CTP products. As such, it is listed here as a "tool", though its purpose extends far beyond the validation of GOES-R products, and it is not a "tool" in the strict sense of the word[15].
Developer: CIMSS[15].
Development Schedule: Development for this tool has been completed[15].
Data Dependencies: GOES-R, GOES, MODIS, VIIRS, and AVHRR L1b/SDRs[15].
Testing Accomplished or Planned: Testing has been completed[15].
POC: Cloud Product Team[15].

D. Appendix D: Acronym List

Acronym	Definition
AART	Algorithm Action Review Team
ABI	Advanced Baseline Imager
ADR	Algorithm Discrepancy Report
AIT	Algorithm Integration Team
ARM	Atmospheric Radiation Measurement
AVHRR	Advanced Very High Resolution Radiometer
AWG	Algorithm Working Group
Cal/Val	Calibration and Validation
CALIOP	Cloud-Aerosol Lidar with Orthogonal Polarization
CALIPSO	Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations
CATS	Cloud Aerosol Transport System
CCR	Configuration Change Request
CIMSS	Cooperative Institute for Meteorological Satellite Studies
CLASS	Comprehensive Large Array-data Stewardship System
CLAVR-X	Clouds from AVHRR - Extended
CMI	Cloud and Moisture Imagery
CONUS	Continental United States
CPL	Cloud Physics Lidar
CRS	Cloud Radar System
CSM	Clear-Sky Mask
CTH	Cloud Top Height
CTP	Cloud Top Parameters
CTp	Cloud Top Pressure
CTT	Cloud Top Temperature
CWG	Calibration Working Group
DOE	Data Operations Exercise
ESRL	Earth System Research Laboratory
ER-2	Earth Resources 2
F&PS	Functional and Performance Specification
FD	Full Disk
FTE	Full-Time Equivalent
GOES	Geostationary Operational Environmental Satellite
GOES-R	GOES R-Series
GORWG	GOES-R Series Operational Requirements Working Group
GRB	GOES Rebroadcast

Acronym	Definition
HRR	Handover Readiness Review
IDPS	Interface Data Processing Segment
JPSS	Joint Polar Satellite System
L1b	Level 1b
L2	Level 2
McIDAS	Man-computer Interactive Data Access System
MODIS	Moderate Resolution Imaging Spectroradiometer
MOST	Mission Operations Support Team
MRD	Mission Requirements Document
MSFC	Marshall Space Flight Center
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NCEI	National Centers for Environmental Information
NCEP	National Center for Environmental Prediction
NCEI-CO	NCEI - Colorado
NWP	Numerical Weather Prediction
NWS	National Weather Service
OSPO	Office of Satellite and Product Operations
PDA	Product Distribution and Access
PLAR	Post-Launch Assessment Review
PLPT	Post-Launch Product Test
PLT	Post-Launch Test
POC	Point of Contact
PRO	Product Readiness and Operations
PSE	Program System Engineering
PS-PVR	Peer Stakeholder-Product Validation Review
PUG	Product User's Guide
QA	Quality Assurance
RIMP	Readiness, Implementation and Management Plan
SDR	Sensor Data Records
SEVIRI	Spinning Enhanced Visible and Infrared Imager
SIPS	Science Investigator-led Processing System
SPOT	System Performance Operational Test
SSEC	Space Science and Engineering Center
STAR	Center for Satellite Applications and Research
TBD	To Be Determined
VIIRS	Visible Infrared Imaging Radiometer Suite